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Acceptance of renewable energy innovation in Brazil—case study of wind energy

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Abstract

The paper presents some outputs of renewable energy power plants in Brazil, focusing in the case of wind energy. The information data are mainly acquired from a project developed by the authors with financial resources of Electric Energy National Agengy (ANEEL), United Nations Development Program (PNUD) and Ministry of Science and Technology (MCT). It was used as the socio environmental impacts to evaluate the acceptance aspect, using as examples some case studies implemented in Brazil and the previous experience of the authors.

Keywords: Renewable source; Wind energy; Social and environmental indicators

Contents

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1. Introduction

It is very important to study the best way to insert alternative sources in the Brazilian national grid by the growing awareness of the need to reduce the impact of human activities in such a way as to offer more energy in a sustainable environment. The Brazilian national grid has a total of 1415 generating enterprises, with an installed capacity of 99,485 GW, causing regional and cross-boarder conflicts for the use of soil, water and atmospheric pollution both global and local (Table 1).

Wind energy presents several advantages when compared with other energy sources used in Brazil such as nuclear, hydro and thermo electricity. Its most important attractiveness relates to the relatively low environmental impacts. Nevertheless, several socio-environmental impacts need to be deeply analyzed to reduce the barriers for the acceptance of the wind enterprises. The use of wind energy can be domestic but also can be more complex as in the case of systems linked to the public grids.

Up to the end of 2002, more than 40,000 large Aeolic turbines were in operation in the world, with an installed capacity on the order of 32,500 MW. More than 50,000 new jobs were created and a solid industry of components and equipments was developed. The Aeolic turbine industry is currently growing at over 30% a year with a turnover of 2 billion dollars a year in sales. The forecast for 2007 is an installed capacity of 58,632 MW. In Europe, it is expected that 10% of all energy will be wind-generated by 2030.

In Brazil, the use of the wind to generate electrical energy is still on a small scale, especially considering the great wind potential in Brazil. In 2001, the Ministry of Mines and Energy (MME) through the Electrical Energy Research Center (CEPEL), published the Atlas of Brazilian Aeolic Potential, with information about the behavior of the wind all over the country. This Atlas estimates a potential of 143.47 GW for winds with an average annual velocity equal to or greater than 7.0 m/s, making available an annual estimated generation of 272,220 TWh/year, for which an area of 71,735 km^2 would be necessary (0.8% of the national territory). This projection takes as a basis an average occupation density of 2 MW/km^2 and performance curves for turbines of a height of 50 m. The Atlas shows some special privileged areas, including mountain regions, the coast of the northeast, specific stretches of the south and reasonable average velocities in various parts of the country.

From the point of view of the costs of generation, it is possible to produce electricity from Aeolic sources at globally competitive prices—from US$ 50 to 70 per MWh, measured at various locations in Brazil by the Brazilian Center for Aeolic Power. For beginning results, with the recent changes in regulation standards in the electrical sector, total Aeolic power in operation in the country rose by more than 14 times in the last seven years, that is, from around 2 MW in 1997, to 28.6 MW in April 2005, with medium-sized Aeolic turbines connected directly to the power grid. Also, there are hundreds of windmills for pumping water and dozens of small wind turbines in isolated places for charging batteries, telecommunications systems and rural electrification.

Table 1
Brazil—power energy grid—2005. Enterprises in operation and their socio-environmental impact

Type of plant	Installed capacity		(%)	Socio-environmental impact**
	Number of plants*	(kW)*		
Hydro	569	69,668,107	70.03	Conflicts in the use of soil and water
Gas				Greenhouse gas emissions
Natural	70	8,975,744	9.02	
Process	24	901,800	0.91	
Petrol-oil				Greenhouse gas emissions, acid rain and local atmospheric pollution
Oil diesel	458	4,088,875	4.11	
Oil residual	19	1,168,278	1.17	
Biomass				Conflicts in the use of soil, atmospheric and local water pollution
Cane waste	217	2,170,654	2.18	
Black liquor	12	665,572	0.67	
Wood	22	199,632	0.20	
Biogas	2	20,030	0.02	
Rice husk	2	6,400	0.01	
Nuclear	2	2,007,000	2.02	Risk of accident and nuclear waste
Coal	7	1,415,000	1.42	Greenhouse gas emissions, acid rain and atmospheric and local water pollution
Aeolic	11	28,625	0.03	Obstruction to migrating birds, visual impacts, noise impacts, demand for land
Imported				Border conflicts over land usage and ware and atmospheric pollution (global and local)
Paraguay		5,650,000	5.85	
Argentina		2,250,000	2.33	
Venezuela		200,000	0.08	
Uruguai		70,000	0.20	
Total	1415	99,485,717	100	

Source: [1,2].
*Installed Capacity from National Energy Balance—www.mme.gov.br/ben
**Based on authors report for United Nations Development Program ‘‘Energy Comsumption and Planet Warming’’ (Consumo de Energia e Aquecimento do Planeta), IVIG/COPPE/UFRJ, 2001.

In the medium term, ANEEL (National Agency for Electricity) has issued permits for 146 businesses working with Aeolic sources with a total of 6679.153 MW, which should come into operation in the next 5 years (2006–2010). From the economic and technical point of view, it is possible, without undermining the Brazilian power production system, to install at least 12,000 MW in the next 10 years. Some initiatives point out the incentive to wind energy in Brazil. The Inventory of the Aeolic Potential in the Southeastern region of Brazil (IPERS), is a project conceived together with the Brazilian Aeolic Atlas Project (AEBr), both carried out in the ambit of the BRA/00/029 Project. The BRA/00/029 project, sponsored by the United Nations Program for Development (PNUD) and managed by ANEEL, was created to give continuity to the implementation of the activities previewed in the technical-scientific cooperation agreement between MCT and ANEEL, in December 1998, and begun in the BRA/95/G31 Project. This project had the participation of two researchers who integrated an Aeolic subproject that was carried from 1 November 2001 to 8 March 2002. Another important initiative is the wind database—there is an agreement underway at the moment involving the Department of Mechanical Engineering

UNIFEI, (Federal University of Itajubá), through the Foundation of Research of Itajubá (FUPEPE) and the Laboratory of Alternative Energy Sources (LAFAE) with the MME for the development and implantation of a database for winds which will carry the data necessary for a technical and economic feasibility analysis for the enterprises that would make use of the Aeolic energy.

An important Aeolic energy project in Brazil is the wind farm of the Park of Rio do Fogo. The Enerbrasil—Energias Renováveis do Brazil, an independent company producing energy authorized by Aneel, will begin the construction of the Rio do Fogo Aeolic Park in the first semester of 2006. This wind park was chosen to be built within the Incentives to Alternative Energy Program (PROINFA). It will be built in the State of Rio Grande do Norte, in the municipality of Rio do Fogo, which is located about 60 km to the north of Natal, the capital city of the state, on the coast. The park's total installed power will be 49.3 MW and the turbines to be installed will be manufactured in Brazil by Wobben Windpower, a subsidiary of the German company Enercon. This will be the company's first Aeolic Park in Brazil.

Another important initiative is the approval by the Brazilian National Bank for Socio Economic Development for the construction of a Aeolic park of Osório, in the state of Rio Grande do Sul. The capacity of this park will be 150 MW, which will be considered the biggest in Brazil and the second in the world and it will employ around 500 direct jobs. According to the Permanent Forum of Renewable Energy, coordinated by the Science and Technology Ministry, until the end of 2005, around 1600 Aeolic turbines were foreseen, each with maximum capacity of 600 kW.

Table 2 presents the main projects of Aeolic energy installed in the country.

According to Table 2, Ceará is an important state in terms of Aeolic energy in Brazil. The Energy Company of Ceará (COELCE) estimates that the litoral of Ceará presents the highest potential for Aeolic energy with regular winds during the whole year. A big project of 60 MW in the litoral of Ceará is foreseen, in the municipalities of Paracuru and Camocim, 30 MW for each city, 207.000 MWh/ano.

The rise of the participation of Aeolic power in the national power matrix needs to be planned so that it is inserted into the mix of the Brazilian power system. It is necessary to carry out regional studies involving social-economic and environmental feasibility taking into account impacts on the transmission and distribution system, and also an evaluation of social and environmental repercussions. Until now, there are no formal monitoring activities with the aim of assessing the effects, for the interested populations, of wind energy projects surrounding their localities. Nevertheless, some informal communications are available. The representatives of the Municipal governments of Camocim and Paracuru in Ceará, for example, declared to the authors of the present paper that the local population was asked about the future wind projects in their cities. They received general informations with photos of previous enterprises in other localities. According to them, the people considered the wind turbines a "very beautiful sightseeing". Besides, it was declared that the majority of the communities, linked to fish activities, approved the projects because they considered that it would result in new activities of tourism, more job creation and financial resources. There are not more details about the conditions and methodologies of the researches.

2. Brazilian experiences—wind energy

The first wind project in Brazil to generate electricity was installed in 1992 in Fernando de Noronha Island, state of Pernambuco, northeast of the country. It is considered a world

Table 2
Main projects of Aeolic energy installed in Brazil, 2005

State	Local	Companies	Installed capacity	Energy (MWh/yr)
Ceará	Porto do Mucuripe	TAKE	1.2 MW	3800
Ceará	Usina da Prainha	Wobben—Enercon	10.0 MW	35,000
Ceará	Usina Taíba	Wobben—Enercon	5.0 MW	17,500
Minas Gerais	Usina do Morro do Camelinho	TAKE	1.0 MW	800
Pará	Usina de Joanes	Bergey	40 kW	Without information
Paraná	Palmas I	Wobben—Enercon	2.5 MW	7000
Paraná	Palmas II	Wobben—Enercon	9.5 MW	33,600
Paraná	Palmas III	Wobben—Enercon	50 MW	Without information
Pernambuco	Usina de Fernando de Noronha	Folkcenter	90 kW	Without information
Pernambuco	Centro de Testes de Olinda	Folkcenter	30 + 225 kW	—

Source: Authors.

paradise due to its ecological diversity. From this experience, other projects were developed in Brazil.

2.1. *Power plant of Fernando de Noronha Island*

In 1992, the Energy Company of Pernambuco (CELPE), in partnership with the Company *Folkcenter* from Denmark and the Group of Wind Energy of Federal University of Pernambuco, installed the first big wind turbine for commercial operation in South América. Before that, the Fernando de Noronha Island used thermoelectricity based on diesel oil with big environmental impacts. The equipment has capacity of 90 kW and a tower with 23 m high and propellers with diameter of 17 m.

Some problems related to this first Brazilian experience of Aeolic energy ocurred. The first tentative to put the turbine in operation did not work at all. It was reported by the *Journal of Technology of Pernambuco* (edition of April 1993), "as an unusual component in the beautiful island landscape, indifferent to the tentatives to force it starting work". As the engineers from Denmark were not in Brazil anymore, the problem had to be solved by Brazilian engineers but only after 3 months of tentatives. That is why the technology received the surname of 'Black Box'.

The Aeolic energy represents around 4% of the total electricity consumed in the Fernando de Noronha Island nowadays. ANEEL, the Brazilian Center of Aeolic Energy (CBEE) and the Government of Pernambuco intends to increase the Aeolic energy in the Island of Fernando de Noronha to 22% as a first step and 50% as a second step.

Some characteristics of the system running in Fernando de Noronha Island: capacity of 90 kW, a tower with 23 m high, propellers with diameter of 17 m, tower with square base, nominal tension 3–380 Vrms/60 Hz, wind velocity = 12 m/s and start = 3.5 m/s.

2.2. *Power plant of Camelinho Hill*

The Company of Energy of Minas Gerais (CEMIG) realized measurements and evaluations of the wind conditions in the Hill of Camelinho during 1983 and 1984. The results showed that the region had great potential to develop Aeolic energy projects.

New studies were realized to implement a large wind system in the local. In 1992, this project idea was framed in the Eldorado Program of the German Ministry of Science and Technology, which offered 70% of the total necessary resources for the project implementation.

The power plant of Camelinho was installed in 1994, with capacity of 1 MW, total cost of US$ 1,540,000. From this total, US$ 790,000 (51%) were paid by the German Govenment Eldorado Program and US$ 750,000 (49%), were financed by CEMIG.

According to the project information, the local average velocity was estimated between 6 and 7 m/s, for 30 m high, and a yearly production of around 1500 and 1800 MWh was foreseen . Some characteristics of the system are four turbines with 250 kW each, horizontal axis rotor, three propellers with diameter of 26 m, conic tower with 30 m high, nominal wind velocity of 14 m/s with start velocity of 3 m/s.

2.3. Power plant of Palmas in the State of Parana

Opened in November 1999, the Aeolic Central of Parana, a joint company of Parana Electric Company (COPEL) (30%) and Wobben Wind Power (70%), a Brazilian subsidiary of the German Enercom, is already at commercial operation. According to Wobben, the investment was around US$ 1 million per installed MW.

The capacity of plant is 2.5 MW, with five aerogenerators with 500 kW each. The plant is installed in the Municipality of Palmas in the south region of the state. The first phase of the project foresees the availability of energy to the COPEL system during 20 years.

The plant of Palmas works with average wind velocity of 7.5 m/s, around 0.5 m/s superior to the national average of wind velocity. Nevertheless, the plant only acquires its nominal capacity with wind up to 12 m/s.

According to COPEL, the plant is able to produce 6.5 million kWh per year, enough to supply a Municipality with 15,000 inhabitants. It is interlinked to the transmission system of 34.4 kV with 37 km of lines.

The power plant of Palmas is installed in a local with altitude of 1300 m related to the sea level. The aerogenerators are 44 m high, sustained by steel tubular towers. Each aerogenerator has three fiberglass propellers. The energy production requires a minimum wind velocity of 3 m/s and this must be present approximately 95% of the time.

2.4. Power plant of Harbor of Mucuripe

From the data obtained by the Aeolic Map Project of the State of Ceara [3], the COELCE projected and constructed an Aeolic park with 1.2 MW in Fortaleza, in Praia Mansa—Harbor of Mucuripe.

The park was a result of cooperation of several enterprises; four Aeolic turbines were utilized, manufactured by the Tacke Windtechnique, with nominal potential of 300 kW each and 33 m of the rotor diameter. The project was framed by the German Government Eldorado Program, which supported 50% of the cost of the enterprise.

2.5. Power plant of Taíba

According to Wobben, the investment was around US$ 1 million per installed MW. The power plant has 5 MW of capacity, 10 aerogenerators with 500 kW each. It is located in the

Municipality of São Gonçalo do Amarante, in Taíba Beach, litoral of Ceara. It was constructed on movable sand dunes and occupies an area of 100 ha.

The aerogenerators are installed at 44 m high, sustained by tubular steel towers. The aerogenerators have three fiberglass propellers with 20 m length. Energy production starts from minimum wind velocity of 3 m/s. The rotors follow automatically the direction of air currents maximizing the process. The power plant is controlled, monitored and operated at a distance by computer.

2.6. Power plant of Prainha

With towers and propellers pre-manufactured in Brazil, the Power Plant of Prainha was the first Aeolic plant in the world installed on movable sand dunes. It is in Prainha at the Municipality of Aquiraz, litoral of Ceará state, northeast of Brazil. It occupies 100 ha and the investment was approximately US$ 1 million per MW installed. The capacity of the plant is 10 MW, with 20 aerogenerators of 500 kW each.

3. Conclusion

The operation of wind energy for electricity generation does not pollute the atmosphere and result in a fossil fuel use reduction [4]. However, it demands huge amount of financial resources, technical adaptation requirements and social acceptance for developing countries. The modern tubular tower turbines (the older ones were structured with interlaced metal) apply aeronautic engineering principles to generate energy. The design of the propellers like airplanes wings and the local choice of the site-specific installation have huge influence for the acceptance of the visual impact of an Aeolic enterprise. Besides,

Table 3
Important aspects for Aeolic energy projects

	Wind energy
Generation capacity, etc.	Depending on the complexity degree of the system (since small aerogenerators with 16 m diameter for the rotor to the big aerogenerators with diameter up to 48 m), the *onshore* or *offshore* application and the accessibility for the maintenance, the acceptance of the wind project is affected.
Existent technologies	There are equipments with vertical (darrieus) or horizontal (propellers) axis. Darrieurs result in great wear for the equipments and huge land area is necessary to install because of horizontal shovels for the vertical axis. There are rotors with 1,2,3 or 4 propellers that present different static and dynamic equilibriums which interferes in the so-called vibration problems. Rotors with 3 propellers are considered the best at this aspect.
Materials	At present the equipments are made of fiberglass covered by resin, which minimize the noise pollution, and the towers are made of steel, which result in a light appearance.
Structuring the pieces in the ground	The sightseeing and security feeling about the enterprise vary a lot depending on the local of the site specific. In Brazil, there are wind plants on sand dunes; hills; and pasturelands. The surroundings are affected after a wind plant implementation, as it is necessary to guarantee the wind quality for it. Sometimes, the best place for a wind plant construction is (or may affect) at a private land and the acceptance depends on the landowner.

Table 3 (*continued*)

	Wind energy
Operational and social issues	
How to carry out the pieces of a wind power plant	In general, the pieces arrive by ships. In Brazil, there are wind plants very far from the litoral, such as the Power Plant of Camelinho Hill, making difficult machinery transportation through some ecological protected areas. In the case of Fernando de Noronha Island, the turbine is installed in the Hill what created a problem of socio-environmental impact during the transportation of the equipments. The assembly of the equipments demands attention because of the huge weight of the pieces In Brazil, for the three aeolic plants Prainha, Taíba and Palmas, it was necessary to use a 400 t crane (only one was in the South of the country), and each aerogenerator took 2 days to be set up. Some risks of accident have to be studied.
Job creation; teams for operation and maintenance	In general, small teams are necessary. O&M does not demand many jobs. It is possible to operate, and control at a distance by computers.
Lack of wind energy	There are doubts about the efficiency of wind plants due to the possibility of lack of wind forcing to link the wind energy to a hybrid system with hydro and thermoelectricity. Other doubt relates to the difficult to store the wind energy for later use.
Environmental issues	
Noise impacts	Vary according to equipments' specifications. Turbines multivane fans are usually noisier.
Visual impacts	That is one of the most critical problems to be considered in a wind power plant in Brazil. There is no awareness of the interference of a wind plant in a landscape sightseeing. The information about this type of energy source emphasizes mainly the bucolic aspect of the Aeolic energy. Plants of Taíba and Prainha in Ceara state are 1500 m from the seashores, and the tourists can use the beaches. In these particular cases, the aerogenerators are considered "postal cards" of the region, attracting lots of visitors to the local.
Birds route impacts	It is a very important issue in Brazil cases due to the migration of several birds in the country.
Financial and economic issues	
Wind energy costs	This kind of source needs subsidy in Brazil. The kWh is too much expensive than the hydro, biomass, and thermoenergy sources. The majority of the equipments has to be imported which is difficult for private investors initiatives. Exchange time for the investments is around 10 years, depending on the stability of the economy policy. There is some expectation of acquirement of carbon credits certifies from wind projects by the replacement of fossil fuel energy power plants.

other fundamental issues are considered for the evaluation of the acceptance of wind power projects mentioned in Table 3.

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